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Dalbergia sissoo Roxb. Sissoo, Indian Rosewood

Leguminosae (Papilionoideae) Legume Family

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John A. Parrotta

Sissoo (*Dalbergia sissoo* Roxb.), or Indian rosewood, is a handsome, fast-growing, medium-to-large deciduous tree native to south Asia, and is greatly valued for its timber (fig. 1). Tolerant of a broad range of climatic and soil conditions, it is widely planted in tropical countries, especially in arid and semiarid regions, for timber, fuelwood, fodder, shade, and stabilization of eroded landscapes.

HABITAT

Native Range

Sissoo is native to the Himalayan region and adjacent valleys of northern India, Pakistan, Nepal, and Bhutan, from the Indus to Assam (fig. 2). Within this region, it grows at altitudes of up to 1,300 m, although it is generally restricted to sites below 900 m (*7, 11*). It is extensively planted along roads and canals throughout south Asia and is also used as windbreaks, for erosion control, in orchards, and in irrigated plantations. In India, sissoo is grown more extensively than any tree except teak (*Tectona grandis* Linn. f.), and Pakistan has over 100,000 ha of irrigated sissoo plantations (*16*). It is widely planted in tropical countries for wood and shade and has become naturalized in many localities, including southern Florida (*11*).

Climate

Sissoo is adapted to a seasonal or monsoonal climate, with total annual rainfall ranging from 500 to 4000 mm and a dry season of up to 6 months (*27, 28*). Sissoo is both frost-hardy and drought-resistant (*11, 27*). In the native range of sissoo, the mean annual temperature ranges from 18 to 26 °C. Mean maximum temperatures in the hottest months range from 35 to 45 °C, and the mean minimum temperatures in the coldest months range from −2 to 5 °C (*27, 28*).

The best growth in natural stands of sissoo occurs in areas where annual rainfall exceeds 3000 mm, with annual maximum and minimum shade temperatures of approximately 39 and 2 °C, respective (*27*). Irrigated plantations have been successfully established in semiarid and arid regions (*28*).

Soils and Topography

Sissoo grows well in a wide range of soil types, from pure sand and gravel to the rich alluvium of riverbanks (*26, 27, 28*). The species readily colonizes sites with exposed mineral soil, such as flat alluvial terraces and low hills, embankments, landslides, and sandstone cliffs (*27*). While sissoo is not exacting as to soil requirements and grows well in seasonally waterlogged soils (*8*), growth is very slow on poorly aerated sites, such as those with heavy, clay soils (*27, 28*). It is adapted to sandy, coastal sites and is commonly used for reforestation of both saline and alkaline soils in arid and semiarid areas of India (*6, 8*).

Associated Forest Cover

In its native south Asian range, sissoo is most commonly found as a canopy dominant in both dry and moist, early successional, deciduous forests along the sandy or stony banks of rivers in the sub-Himalayan hills and outer Himalayan valleys (*5, 7*). Very young stands, which develop on exposed banks, terraces and islands formed by deposits of coarse alluvium, may be pure or mixed with *Acacia catechu* Willd. or *Tamarix dioica* Roxb. and usually have a grass-dominated understory (*27*). In such forests, sissoo eventually forms a light but generally complete canopy 18 to 25 m

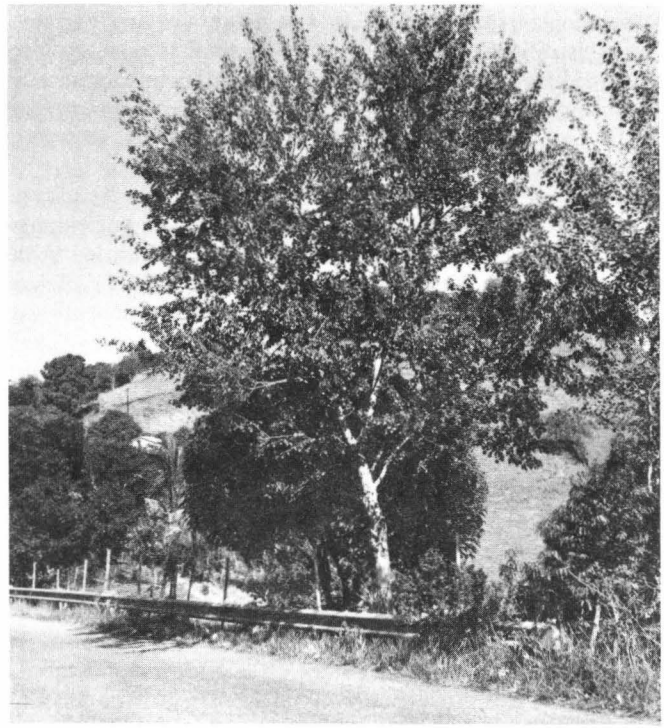

Figure 1.—*Roadside planting of sissoo* (Dalbergia sissoo) *near Lajas, Puerto Rico.*

John A. Parrotta is forest ecologist at the Center for Energy and Environment Research, University of Puerto Rico, Rio Piedras, Puerto Rico, in cooperation with the Institute of Tropical Forestry, Southern Forest Experiment Station, USDA Forest Service, Rio Piedras, Puerto Rico.

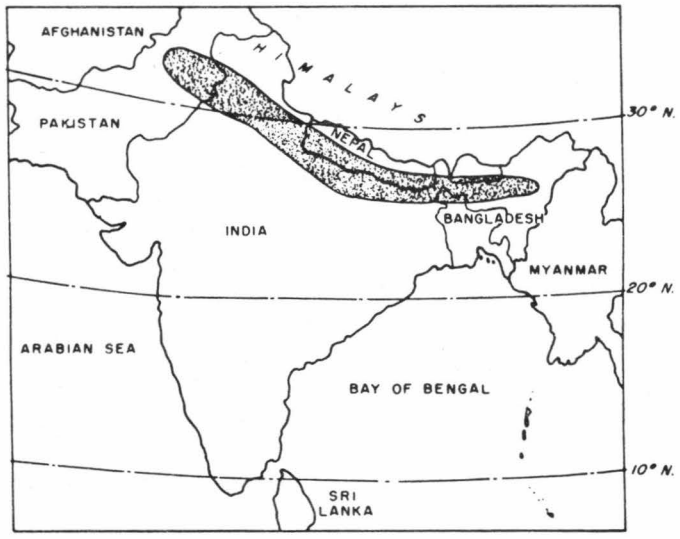

Figure 2.—*Shaded area represents the native range of sissoo,* Dalbergia sissoo *(adapted from* 11*).*

high and is commonly associated with one or more of the following species as a canopy codominant: *A. catechu, Albizia procera* (L.) Roxb. (*18*), and *Populus euphratica* Oliv. (*5*). In these forests, the understory is usually dominated by grasses, particularly in the moister easterly area of sissoo's native range.

In the relatively moist regions of its range, sissoo may eventually be replaced in the canopy by *Bombax malabaricum* DC., *Adina cordifolia* Hook. f., *Albizia procera, Moringa oleifera* Lamk., *Kydia calycina* Roxb., *Lagerstroemia parviflora* Roxb., *Anthocephalus chinensis* (Lam.) A. Rich. ex Walp. (*13*), *Gmelina arborea* Roxb., and *Cedrela* spp. and occasionally by *Holoptelea integrifolia* Planch., which forms pure stands. In the drier western regions, sissoo-dominated successional forests tend to develop into dry deciduous forests of varying composition, but commonly including *Ehretia laevis* Roxb., *Holarrhena antidysenterica* Wall., *Odina wodier* Roxb., *B. malabaricum, K. calycina,* and *Premna latifolia* Roxb. (*5, 27*).

In upland forests away from riverbeds within its native range, sissoo tends to occur more as isolated individuals rather than in dense stands, and is often associated with *Pinus longifolia* Roxb. and *Acacia catechu* (*7, 27*). Sissoo also grows along the larger rivers in the plains of southern Punjab and Sind (in India and Pakistan), where annual rainfall is usually less than 400 cm, on loamy, sandy, and sometimes saline soils. In such areas, sissoo is associated with *Populus euphratica* as a canopy codominant, with a lower canopy commonly including *Tamarix dioica* Roxb. and *A. farnesiana* Willd. (*5*).

LIFE HISTORY

Reproduction and Early Growth

Flowering and Fruiting.—Flowering closely follows leaf flushing, which occurs from January to February in India (*2*). Flowers are formed in branching, hairy, axillary panicles of short racemes 5 to 10 cm long and are often produced on trees as young as 2 years old. Flowers are numerous, small (about 1 cm long), whitish or yellow in color, pea-shaped, and fragrant, with a five-toothed calyx. The corolla has five petals, two narrow wings, and a narrow keel. Nine stamens are united into a broad stalk. The stalked, hairy pistil has a narrow one-celled ovary containing few ovules, a short style, and a dot stigma (*11*).

Fruits are oblong, flat, thin pods pointed at both ends, light brown in color when ripe, 3 to 7.5 cm long and 1 to 1.2 cm wide (*11*). Each pod contains between one and five seeds (*11*). The pale green pods form very rapidly after flowering and ripen from November to January (*2, 27*). While the bulk of the pods fall soon after ripening, some may remain on the tree well into the following flowering season (*2, 27*).

Seed Production and Dissemination.—Seeds are flat, bean-shaped (6 to 8 mm by 4 to 5 mm), light brown in color, with a delicate, papery testa; there are approximately 45,000 to 55,000 seeds per kilogram (*11, 30*). Mature seed pods are dispersed by wind and water. Ripe pods may be collected manually by climbing trees and picking the fruits or by shaking the branches and picking the fruits from the ground (*27*).

Seedling Development.—While sissoo never regenerates under the parent canopy, natural regeneration is nonetheless abundant along stream and riverbanks where the pods have been carried by floods (*2, 5*). Under natural conditions seeds germinate on the soil surface following partial decay of indehiscent pods, generally early in the rainy season, 3 to 6 months after pods fall to the ground (*27*).

While seeds may be sown without special treatment, it is recommended that they either be soaked in water at room temperature for 24 to 48 hours or in concentrated H_2SO_4 for 45 to 60 minutes prior to sowing to facilitate rapid and uniform germination (*28, 30*). Seeds reportedly germinate best at 30 °C (*17*).

Seed germination is generally good, between 70 and 95 percent for fresh seeds, and occurs within 6 to 15 days of sowing (*28*). Seeds remain viable for 1 to 2 years when stored in airtight containers under dry, cool (5 to 22 °C) conditions (*21, 28*).

The factors favoring seedling development are: an abundance of light (*11*), sufficient growing space, high soil porosity, absence of weeds, and a plentiful water supply (*27*). Seedlings respond very well to periodic weeding and surface soil loosening in the nursery (*27*).

Containerized seedlings raised in Nepal reached plantable size (average height: 24 cm; average root collar diameter: 2.9 mm) 14 weeks after sowing (*29*). Under optimal conditions, seedlings may grow to 1.5 m in height during the first year (*27*). At 3 years, average seedling heights generally range from 0.6 to 4.1 m under nonirrigated conditions (*28*).

Plantations may be established using containerized seedlings, stumped seedlings, branch or root cuttings, or transplanted root suckers (root sprouts) (*26, 28*). Direct sowing has been recommended as the most economical means of establishing large-scale plantations in India (*27*).

Vegetative Reproduction.—Sissoo coppices well, but reproduces better from root suckers. When managed as a coppice crop, there is evidence that the stumps begin to lose their vigor after two or three rotations (*17*). Propagation by root suckers is favored by cutting stems just below the soil surface (*7*).

While sissoo is relatively difficult to propagate from stem and branch cuttings without hormone treatments, exogenous application of auxins (IAA, IBA, and NAA) has been found to greatly improve survival and growth rates (*19, 22*). Viable plantlets and healthy seedlings have been produced through in vitro culture (tissue culture) of cotyledon tissue (*3*).

Sapling and Pole Stage to Maturity

Growth and Yield.—Mature trees may attain a maximum height of 30 m on moist sites (10 to 15 m in semiarid regions) and stem diameters at breast height (d.b.h.) of up to 80 cm (*17, 22*). Trees are characterized by a stem that is often curved and crooked, with gray, scaly, and deeply furrowed bark and a rounded, open crown of spreading branches. Depending on site conditions, sissoo may be deciduous or semievergreen (*7*). Leaves are pinnately compound, about 15 cm long, and composed of three to five leaflets that alternate on leafstalks along a very slender zigzag axis. The leaflets are nearly round (2.5 to 5 cm in diameter), abruptly short-pointed at the tip, rounded or blunt at the base, smooth edged, and paler green underneath (*12*, fig. 3).

The rate of growth of sissoo is rapid after the first 2 years. Mean heights of 4.0 and 7.7 m at 4 and 6 years, respectively, have been reported (*26*). Under favorable conditions in 15-year-old natural stands in India, an average stem d.b.h. of 28 cm and an average height of 15.4 m were recorded (*7*). Average stem diameter increments of 1.0 to 2.0 cm/yr have been reported for plantations in India ranging from of 5 to 30 years of age (*7, 23, 27*). Mean annual height increments of 0.7 to 1.3 m have been reported in India for 5- to 20-year-old plantations (*27*).

Figure 3.—*Leaves, flowers, and seed pods of sissoo,* Dalbergia sissoo, *(reprinted from* 12*).*

Mean annual stemwood increments ranging from 5 to 8 m^3/ha are commonly reported in south Asia (*23, 28*). In irrigated plantations in India, second-rotation (coppice) yields have been reported to exceed first rotation yields by a factor of 1.5 to 2.2, with mean annual fuelwood yields from 15- to 17.5-year-old coppice plantations reportedly ranging from 9.0 to 12.5 m^3/ha (*27*).

Mean annual wood biomass increments (branch plus stem) in 5- to 20-year-old plantations in northern India and Pakistan range in fresh weight from 1.5 to 9.0 t/ha (*20, 27*). In a 24-year-old plantation established in the tropical dry deciduous forest zone of northern India, total aboveground biomass was estimated to be 162 t/ha ovendry weight; average stem d.b.h. and tree heights in this stand were 23 cm and 19.7 m, respectively (*23*). Total aboveground biomass in a 20- to 25-year-old sissoo plantation in Harayana (India) was estimated to be 56.4 t/ha ovendry weight, of which stemwood comprised 58 percent (*20*). In trials conducted at a site characterized by saline-alkaline soils in India, total aboveground biomass (overdry weight) in 2-year-olds stands was estimated to be 1.0 t/ha (*6*).

In adaptability trials conducted at a subtropical moist site in Guatemala, average tree heights were reported as 1.3, 2.6, 6.2, and 7.9 m at 6, 13, 24, and 33 months, respectively (*4*). Associated mean tree d.b.h.'s at this site were 4.7 and 6.1 cm at 24 and 33 months, respectively. At a subtropical moist site in Puerto Rico characterized by shallow, limestone-derived clay soils, average tree height and stem d.b.h. of trees in a small planting at 50 years were 13.1 m and 28.3 cm, respectively.

In India, sissoo is commonly established in line plantings; in even-aged, clear-felled plantations; in mixed-species plantations; and in coppice-with-standards systems (*27*).

Rooting Habit.—Seedlings produce a vigorous, somewhat fragile taproot and numerous lateral rootlets. Taproot lengths of up to 20 cm have been recorded 1 month after germination, with lengths of up to 1.5 m after 1 year (*27*). Both taproots and lateral roots are commonly covered with nodules in soils inocculated with nitrogen-fixing *Rhizobium* spp. bacteria (*1, 27*).

In a mixed-species plantation in India, an 18-year-old specimen was reported to have a maximum lateral root length of 8.2 m; lateral root diameters for this tree ranged from 1.1 to 9.9 cm (*14*). Total root biomass was reported to comprise 14 percent of the total tree biomass for a 24-year-old tree harvested in India (*23*).

Reaction to Competition.— Sissoo is strongly light-demanding. In dense stands, while understory light levels remain relatively high, weaker trees are shaded and suppressed by more vigorous individuals (*7, 27*). Individual trees tend to grow poorly in closely spaced plantations (*9, 28*). In irrigated plantation spacing trials conducted in Pakistan, average stem d.b.h.'s in 4-year-old stands planted at 2- by 2- m, 3- by 3- m, and 4- by 4- m spacings were 8.6, 10.1, and 11.3 cm, respectively; average tree heights were comparable among spacings, ranging from 8.4 to 8.7 m (*24*).

Recommended spacings for short-rotation plantations in India range from 1.8- by 1.8- m to 2.5- by 2.5- m; a 1.5- by 3.0- m spacing has been found satisfactory as it facilitates weeding (*27*). As a timber crop, sissoo is commonly established at a minimum spacing of 4- by 2- m and managed on a rotation of 50 to 60 years, or in line plantings along roads

and agricultural fields in densely populated areas (*9*). At spacings wider than these, trees tend to develop a more crooked form and a greater number of low branches, making the stem unacceptable for some uses (*24, 27*).

Newly established plantations often require weeding during the early establishment phase. Once established, however, sissoo is one of the few species that can compete successfully with the aggressive weed *Lantana camara* var. *aculeata* (L.) Mold. on sites where the latter is dominant (*26*). Sissoo is recommended for use in agroforestry systems, where it reportedly gives minimal root and shade competition (*28*). In such systems, sissoo is commonly planted in lines, with grain and vegetable crops cultivated between tree rows (*27*).

Damaging Agents.—In the Indian subcontinent, sissoo is reportedly susceptible to attack by a number of pathogens (*15*). The powdery mildew fungus *Phyllactinia dalbergiae* Pirozynski, which appears on the leaves of young plants and older trees (*10, 15*), generally appears late in the growing season and is not believed to cause serious damage (*27*). Pathogens causing leaf spot include *Cercospora sisoo* Syd., *Cochliobolus lunatus* Nelson & Haasis, *Colletotrichum sisoo* (Sydow.) Sutton, *Phomopsis dalbergiae* Sahni, *Phyllachora dalbergiae* Syd. & Butler, and *Phyllosticta sisoo* Died. (*15*). Other pathogens affecting leaves in India include *Botryodiploidia theobromae* Pat., the leaf blight *Colletotrichum gloeosporioides* Penzig, *Cylindrocladium scoparium* Morg., the leaf wilt *Fusarium solani* (Mart.) App. & Wollenw. f. *dalbergiae* Gordon (*15, 17, 19*), and the leaf rusts *Eudarluca caricis* (Fr.) C.Eriks, *Maravalia achora* (Syd.) Arth. & Cunm., and *Uredo sissoo* Syd. & Butler (*10, 15*). *Catenulaster batistae* Aggarwal & Sharma, *Glomerella cingulata* (Stonem.) Spauld & Shrenk., and *Septothyrella dalbergiae* Pavgi & Singh have been reported to affect pods (*15*).

Wood rots reportedly affecting sissoo in India include *Daedalea flavida* Lev., *Daldinia erschscholzii* (Ehrenb.) Rehm., *Favolus canadensis* Klotzsch., *Fomes fastuosus* (L.) Berk., *Ganoderma applanatum* (Pers.) Pat., *G. lucidum* (Leyss.) Kaist., *Hymenochaeta damaecornis* (Link.) Lev., *Irpex flavus* Klotsh., *Marasmius pangerangensis* P. Henn., *Peniophora indica* Thind & Rattan, and *Polyporus gilvus* Schw. (*15*). *Fomes durissimus* Lloyd has been reported as a cause of stump rot (*15*), and *F. lucida* (Leys.) Fr., a rot which appears to spread below ground, reportedly causes considerable damage in plantations (*27*). Sissoo is reportedly resistant to *G. lucidum* root rot during the first 8 to 10 years in plantations, but is highly susceptible thereafter, particularly on sandy sites (*19*). *Nummularia cinnalbarina* P. Henn. has been reported as the cause of a blister canker in sissoo (*15*).

Sissoo reportedly suffers extensive damage in India by the lepidopterous pests *Plecoptera reflexa*, a defoiliator, and *Dichomeris eridantis*, a leaf binder (*19*), and is susceptible to attack by the pinhole borer (*17*). Nursery damage by the cricket *Brachytrypes portentosus* has been reported in India, with the most extensive damage occurring in March, April, and September (*19*). Young trees are reported to be susceptible to termite attack (*27, 28*).

Parasitic plants reported to cause considerable damage to sissoo include *Loranthus longiflorus* (*27*), *Tapinenthus dodoneifolius* (*17*), and, in alluvial forests, the climbers *Dregea volobilis* Benth., *Cryptolepis buchanani* Roem & Sch., and *Acacia pennata* Willd. (*27*). Mixed species plantations are recommended to help combat weed competition and pest damage (*28*).

Sissoo is subject to browsing damage by cattle, goats, deer, camels, and hares; porcupines and rats have been reported to damage root systems (*17, 27*). Trees with shallow root systems, such as those often found in irrigated plantations, are susceptible to windthrow (*27*).

SPECIAL USES

Sissoo is one of the most important timber trees in India. The wood is very hard and close-grained, durable, seasons well, and does not warp or split (*2*). The sapwood is white to pale brownish white, and the heartwood is golden brown to dark brown with deep brown streaks. The wood is moderately heavy to heavy, with a specific gravity of 0.78 to 0.83 g/cm^3; very hard and strong, with a medium coarse texture and an interlocked grain; and diffuse-porous, with inconspicuous growth rings (*11*). The heartwood is extremely durable and is one of the least susceptible to dry-wood termites in India (*11*). Sissoo is used extensively for furniture, paneling, boat building, transmission poles, posts, wheels, boxes, plywood, and general construction. Special uses include musical instruments, carvings, ornaments, athletic equipment, and tool handles (*2, 11*). Sissoo wood makes an excellent fuel; sapwood and heartwood calorific values are reported as 4.9 and 5.2 kcal/g, respectively (*17*).

Young branches and foliage are used as livestock fodder (*11*). Oil obtained from the seeds is used to cure skin diseases. The powdered wood, applied externally as a paste, is reportedly used in the treatment of leprosy and skin diseases (*2*). Sissoo is widely planted in south Asia for erosion control in gullies and on dunes (*28*).

GENETICS

The genus *Dalbergia*, containing about 300 species of tropical and subtropical woody plants, is named for the late 18th century Swedish botanists Nils and Carl Gustav Dalberg (*1, 11*). Other *Dalbergia* species of economic value for their ornamental heartwood include *D. latifolia* Roxb., *D. cultrata* Grah., and *D. oliveri* Gamble (*27*).

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